Direct Manipulation of Interactive Character Skins

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Introduction

- Characters for interactive systems
  - Speed is king
- Linear Blend Skinning (SSD, etc.)
  - Widely used method
- Pros: fast, hardware accelerated
- Cons: hard to author, can look bad
- We address the former

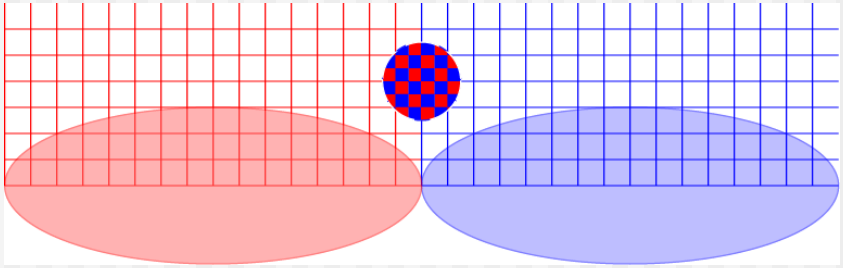
Example

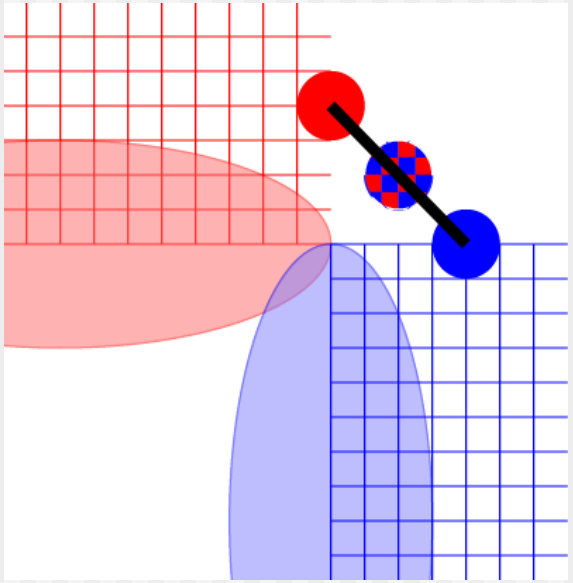
- Current systems
  - *Indirect* manipulation interface
  - Paint parameters over meshes
  - Unclear what is possible
- Instead, let users edit *directly*
  - Drag points explicitly
  - Compute closest achievable position
  - Solve for skin parameters

Video

Linear Blend Skinning

- [Catmull ’72] [Magnenat-Thalmann et al. ’88] [Lewis et al. ’00]
- Place skeleton inside geometry (dress pose)
- Joint ´ Transformation matrix
- Linear blend of joint matrices transforms points





Linear Blend Skin Computation

- Vertex deformed by linear blend of matrices
- Weights affine, usually convex

$$\bar{\mathbf{v}} = \sum_{i=1}^{n} w_i R_i \mathbf{v}_d$$

- R_i = transformation matrix associated with *i*th joint

Linear Blend Skin Authoring

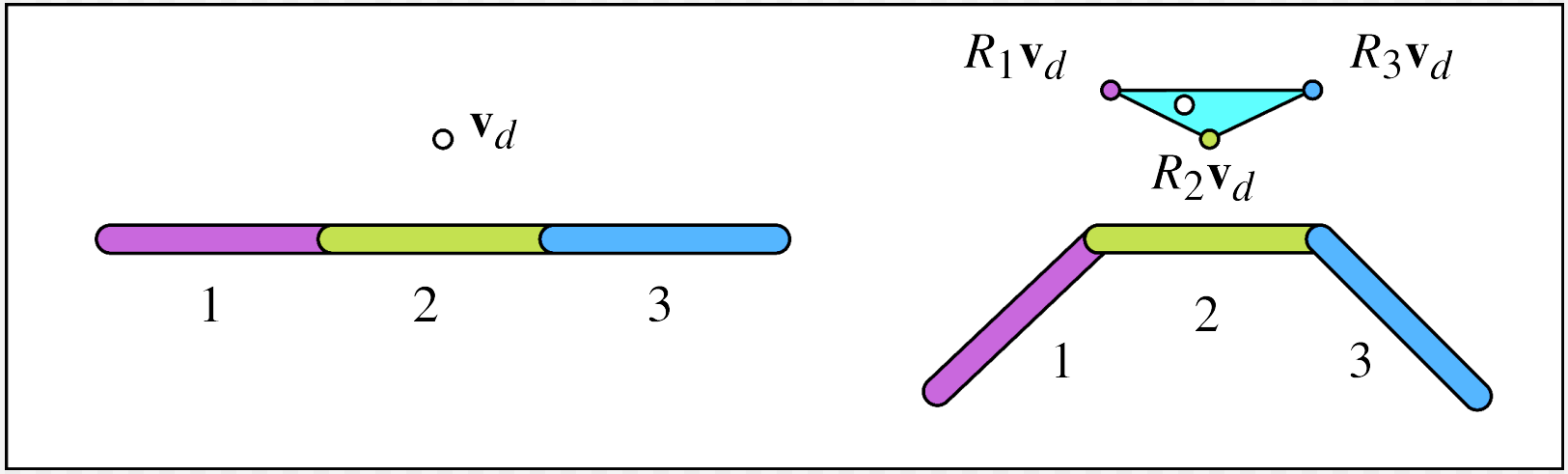
- Must determine
  - Influence set
  - Vertex weights
- Current systems use “painting” UI
  - Select joint, weight, then draw on mesh
  - What deformations are possible?

$$\bar{\mathbf{v}} = \sum_{i=1}^{n} w_i R_i \mathbf{v}_d$$

Range of Possible Deformations

- Valid subspace: What is reachable?
- Affine or convex hull of rigidly transformed vertex

$$\bar{\mathbf{v}} = \sum_{i=1}^{n} w_i R_i \mathbf{v}_d$$

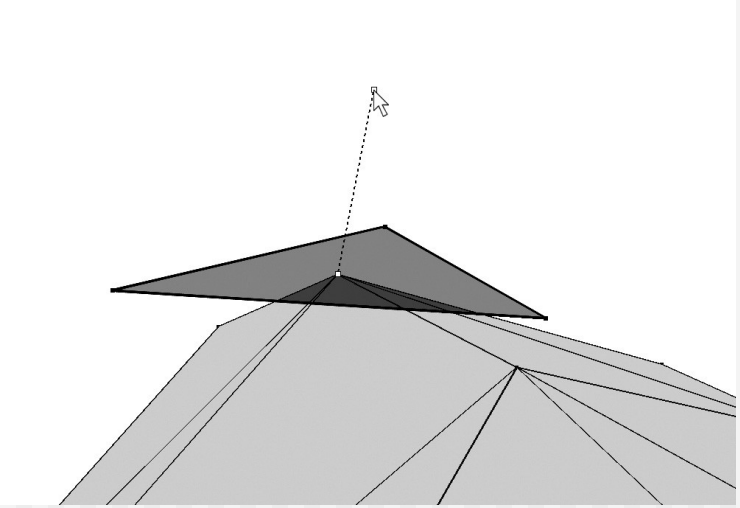


Direct Manipulation

- Algorithm
  - Project onto valid subspace (target **t**)
  - Determine weights so skin achieves **t**

Direct manip. is well known
[Hutchins et al. ’86]
[Schneiderman ’83]
[Sutherland ’63]

Similar work
[Fowler ’92]
[Hsu et al. ’92]



Computing Weights

Let: $w_1 = 1 - \sum_{i=2}^{n} w_i$

Solve:

$$\left[(R_2 - R_1)\mathbf{v}_d \cdots (R_n - R_1)\mathbf{v}_d\right] \begin{bmatrix} w_2 \\ w_3 \\ \vdots \\ w_n \end{bmatrix} = \left[\mathbf{t} - R_1\mathbf{v}_d\right]$$

Guarantees weights are affine.
Does not guarantee weights are convex.

Video

Degeneracies

- If some columns linearly dependent

$$\left[(R_2 - R_1)\mathbf{v}_d \cdots (R_n - R_1)\mathbf{v}_d\right] \begin{bmatrix} w_2 \\ w_3 \\ \vdots \\ w_n \end{bmatrix} = \left[\mathbf{t} - R_1\mathbf{v}_d\right]$$

- Practically
  - More than four influences
  - Valid subspace collapsed in some way
- Happens frequently in practice
  - More than four influences desirable
  - User moves just one joint

Handling Degeneracies

- Quick fix?
  - Disallow more than four influences
  - Perturb joints in other cases
- Geometric projection *guarantees* a convex solution
- Solve a linear program to enforce convexity constraints

Linear Program

- Objective: minimize L_1 change in weights

  Constraint: $-\mathbf{y} \leq \mathbf{w} - \mathbf{w}_p \leq \mathbf{y}$

  Objective: $\min \sum y_i$

- Constraints

$$\left[R_1\mathbf{v}_d \cdots R_n\mathbf{v}_d\right]\mathbf{w} = \mathbf{t}$$

$$\sum_{i=1}^{n} w_i = 1$$

$$\forall i, w_i \geq 0$$

This always has a feasible solution due to the projection step.

Discussion

- Allow users to move groups of vertices directly
- Skin parameters computed automatically
- Allow users to see possible range of deformations
- View edits in multiple poses

Video

Summary

- Method for improving skin authoring for interactive characters
- Users must still define influence sets
- Much more intuitive interaction
  - As close as possible to user’s wishes
  - Clear what is possible
- Compatible with current interface

Thanks

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